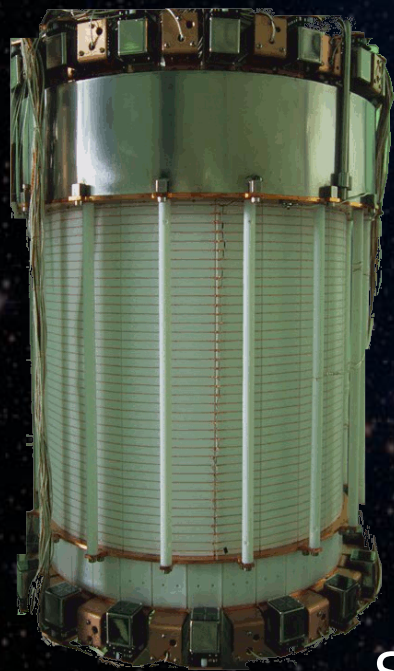
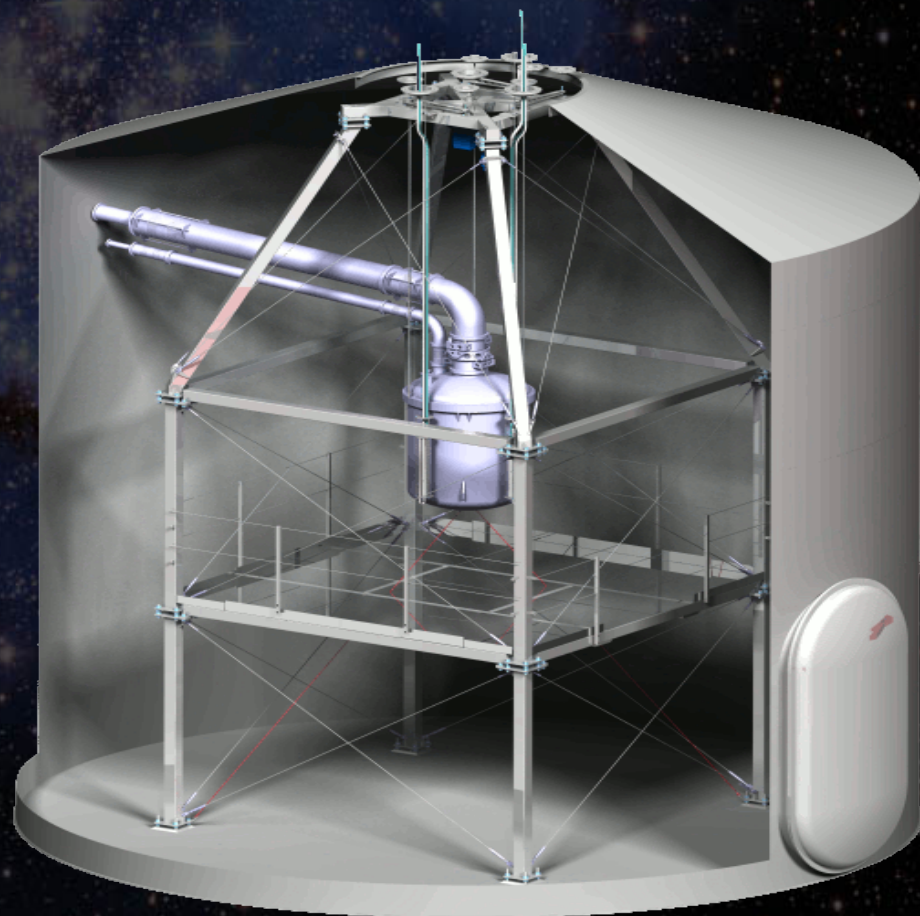


# Searching for Dark Matter with XENON100 and XENON1T



TAUP  
Sept 8 – 13 2013  
Asilomar, CA

Ethan Brown  
On behalf of the  
XENON Collaboration



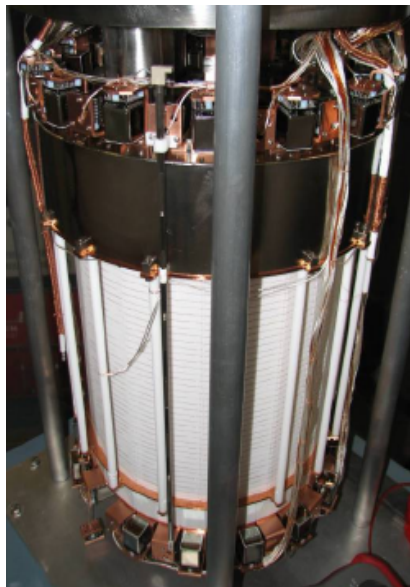
# The Phased XENON Program



2005 - 2007

**XENON10**

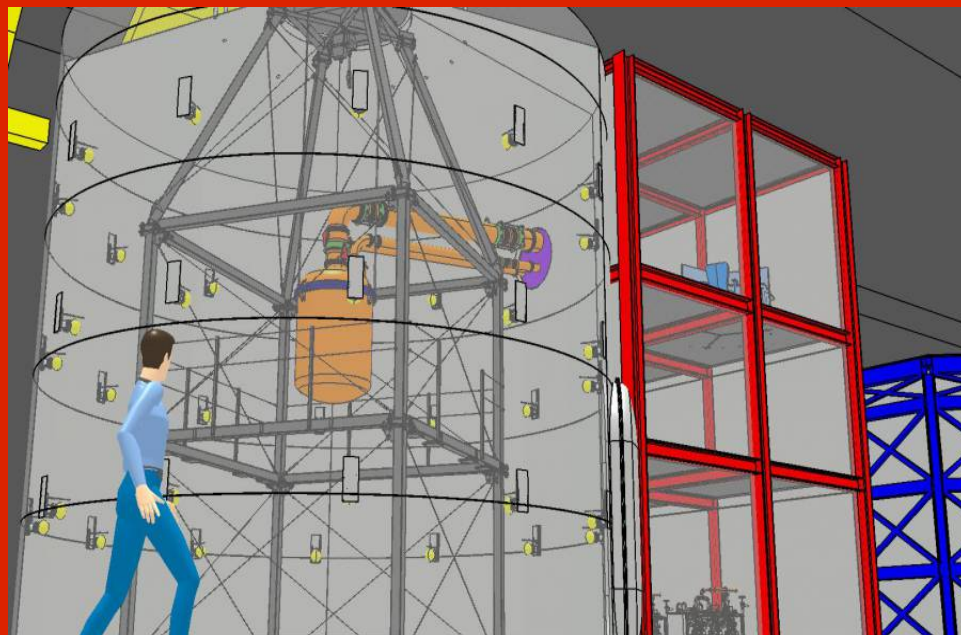
$$\sigma_{\text{SI}} < 8.8 \times 10^{-44} \text{ cm}^2$$



2008 - 201x

**XENON100**

$$\sigma_{\text{SI}} < 2.0 \times 10^{-45} \text{ cm}^2$$



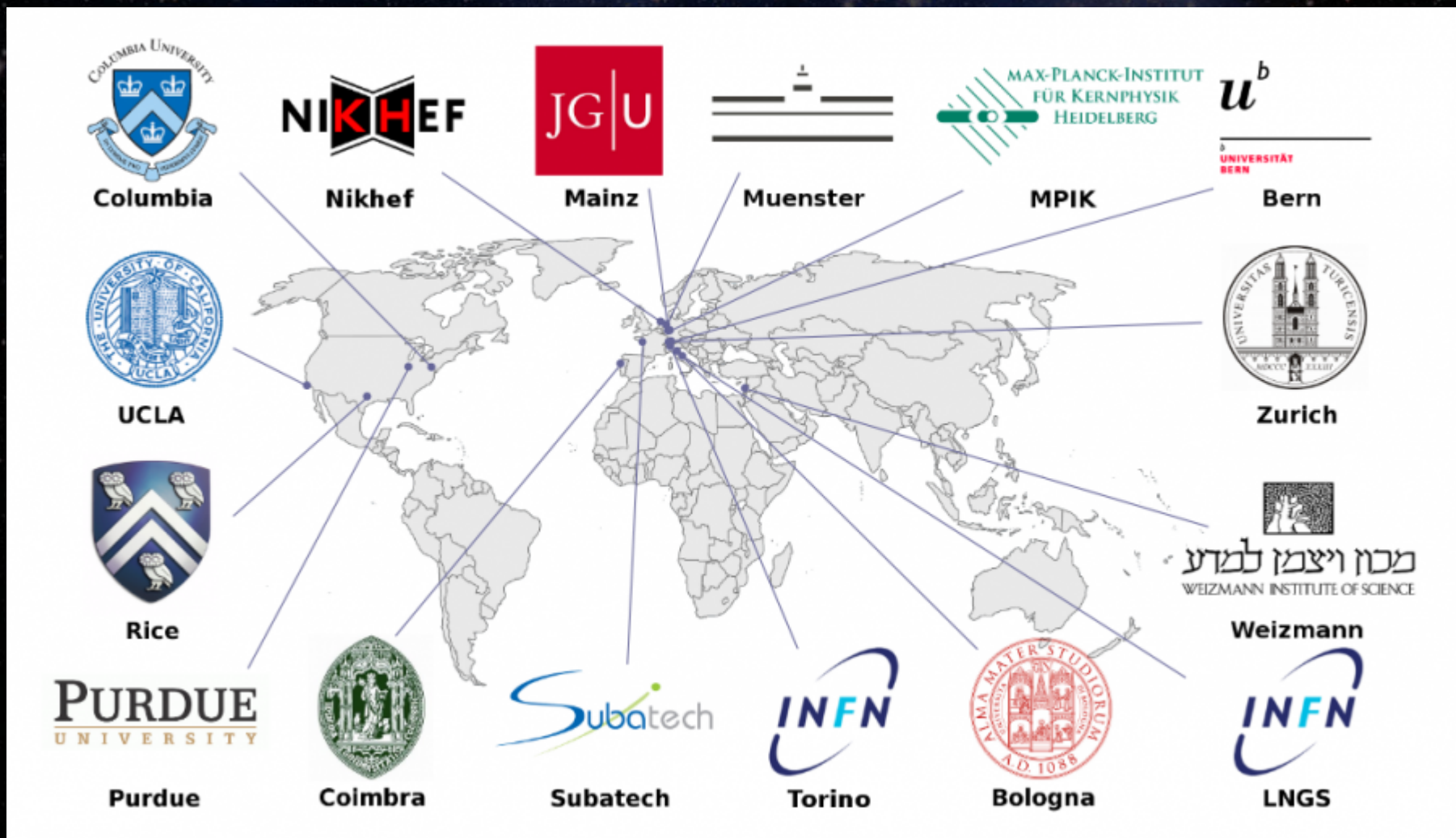
2011 - 2017

**XENON1T**

$$\sigma_{\text{SI}} \sim 2 \times 10^{-47} \text{ cm}^2$$

(projected)

# The XENON Collaboration



# XENON100

TPC:

- 30 cm drift length and 30cm  $\phi$
- 161 kg total (**62 kg** sensitive volume)
- Material screening and selection
- Active liquid xenon veto
- **100x** lower background than XENON10

E. Aprile et al. Phys.Rev.D83:082001,2011

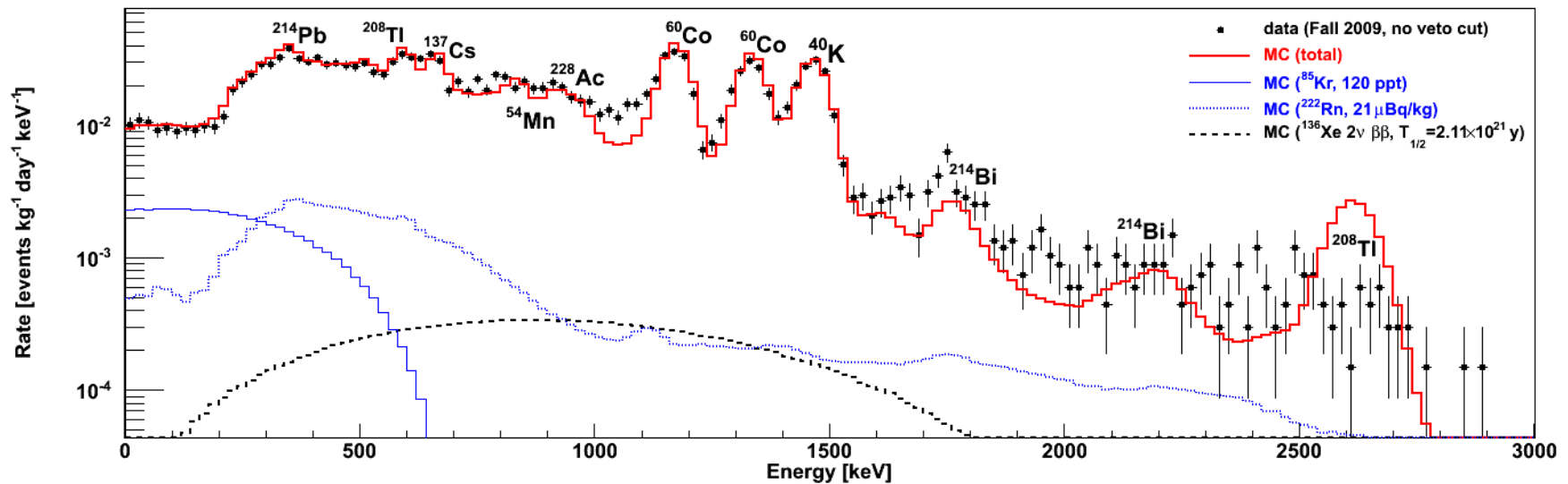
## PMTs:

- ◆ 242 Hamamatsu R8520 in TPC and Active Veto
- ◆ High QE: Bottom tubes > 30%
- ◆ Low Radioactivity: < 10 mBq/PMT



E. Aprile et al. (XENON100), Astroparticle Physics 35, 573 (2012).

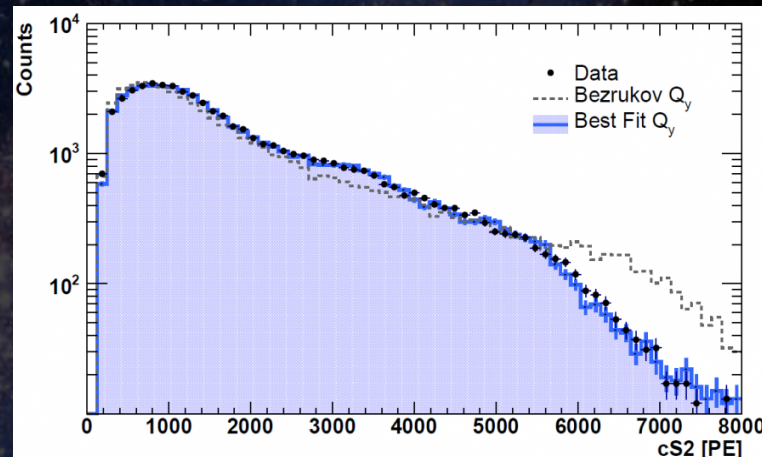
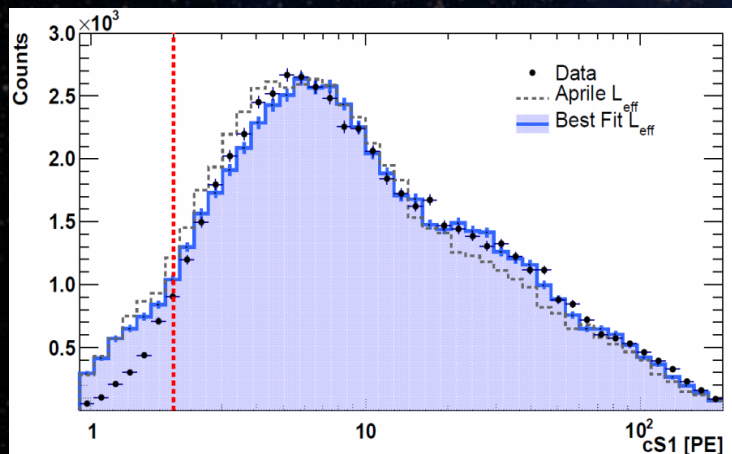
# Backgrounds in XENON100



- Measured ER background in agreement with MC
- No fine tuning of rate!
- Activity taken from screening measurements
- Rate below 100keV  $5 \times 10^{-3}$  evts/kg/keV/d

Astropart.Phys.35:43-49,2011  
Phys. Rev. D83 (2011) 082001

# Data MC Matching



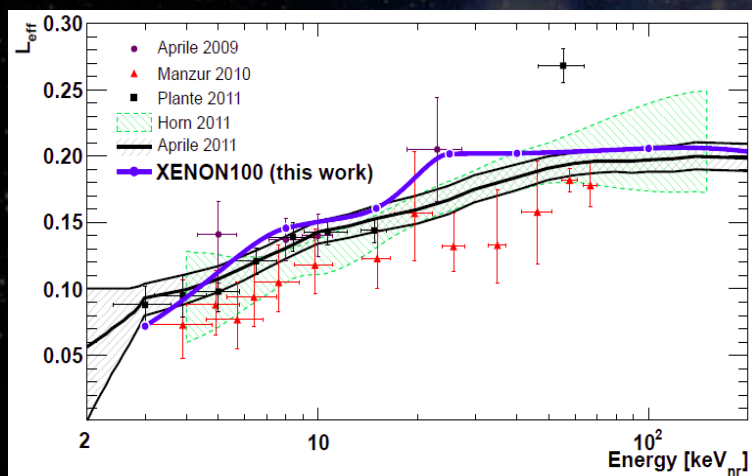
S1 response ( $L_{\text{eff}}$ )

S2 response ( $Q_y$ )

Data from XENON100 and  $L_{\text{eff}}$  measurements  
in excellent agreement with MC

E Aprile et al., (XENON100) Phys. Rev. D 88, 012006 (2013)

G Plante et al., Phys. Rev. C 84, 045805 (2011)



# 225 Day Dark Matter Search

Data collected from Mar 2011 – May 2012  
Blinded analysis performed  
BG prediction (for cut based analysis):

NR:  $0.17^{+0.12}_{-0.07}$  XENON100 (2013) arXiv:1306.2303

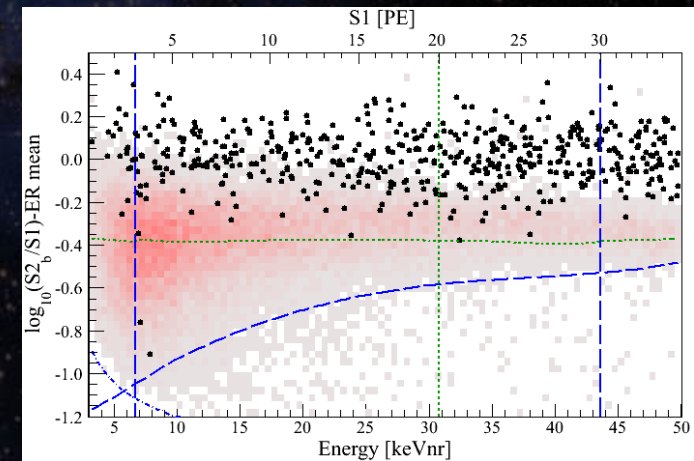
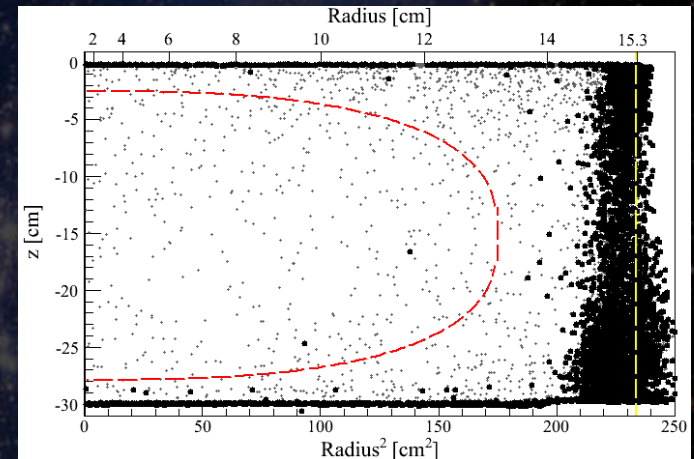
ER:  $0.79 \pm 0.16$

Total:  $1.0 \pm 0.2$

RESULT: 2 events in benchmark region

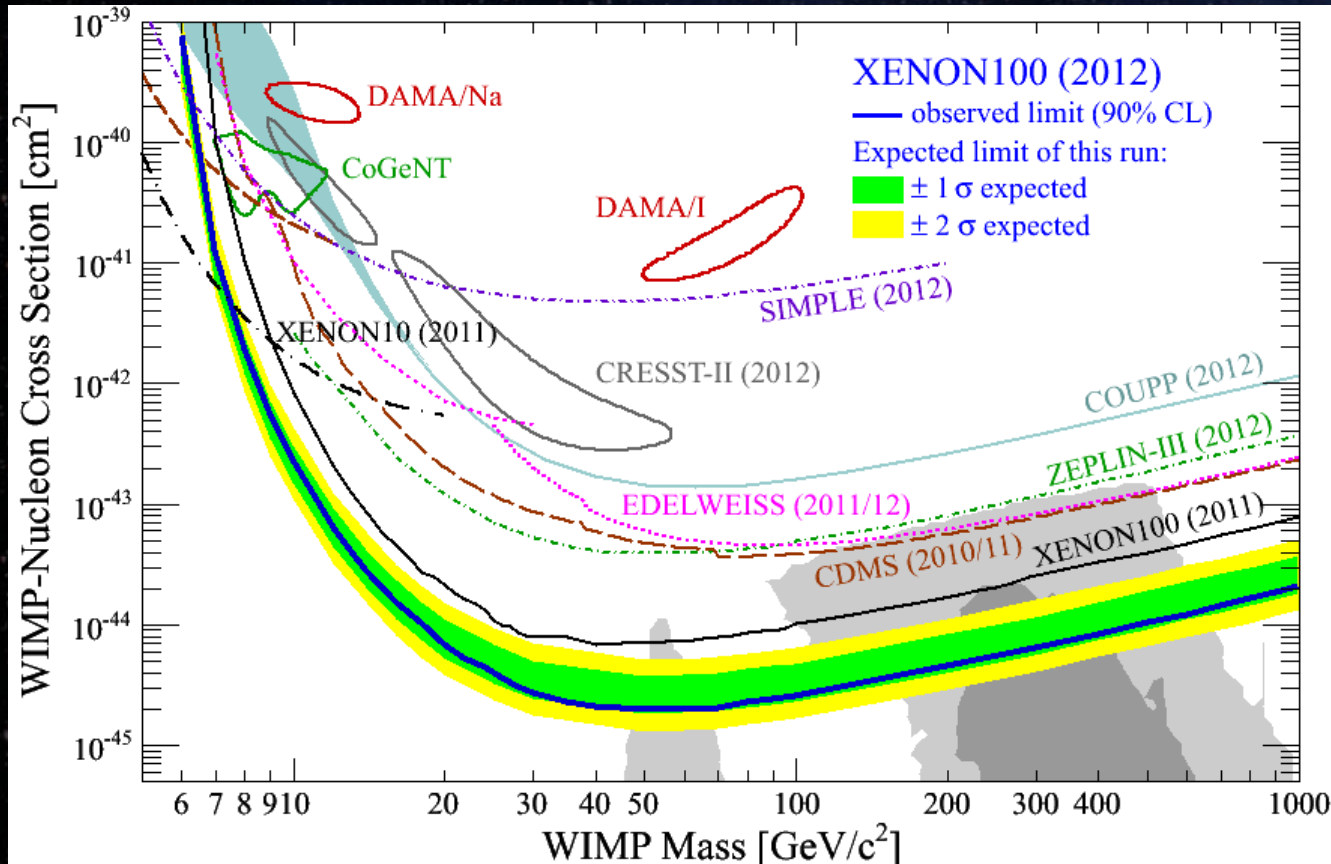
Profile Likelihood Analysis:

Cannot exclude BG only hypothesis  
→ Limit derived



E. Aprile et al. (XENON100), Phys. Rev. Lett. 109, 181301 (2012)

# Spin Independent Results



Results inconsistent with dark matter signal

Set upper limit on WIMP-nucleon SI cross section

World's most sensitive limit to date:

$$\sigma_{\text{SI}} < 2.0 \times 10^{-45} \text{ cm}^2$$

for 50 GeV/c<sup>2</sup> WIMP

E. Aprile et al. (XENON100), Phys. Rev. Lett. 109, 181301 (2012)

# Spin Dependent Search

SD cross section, in terms of spin structure function  $S_A(q)$

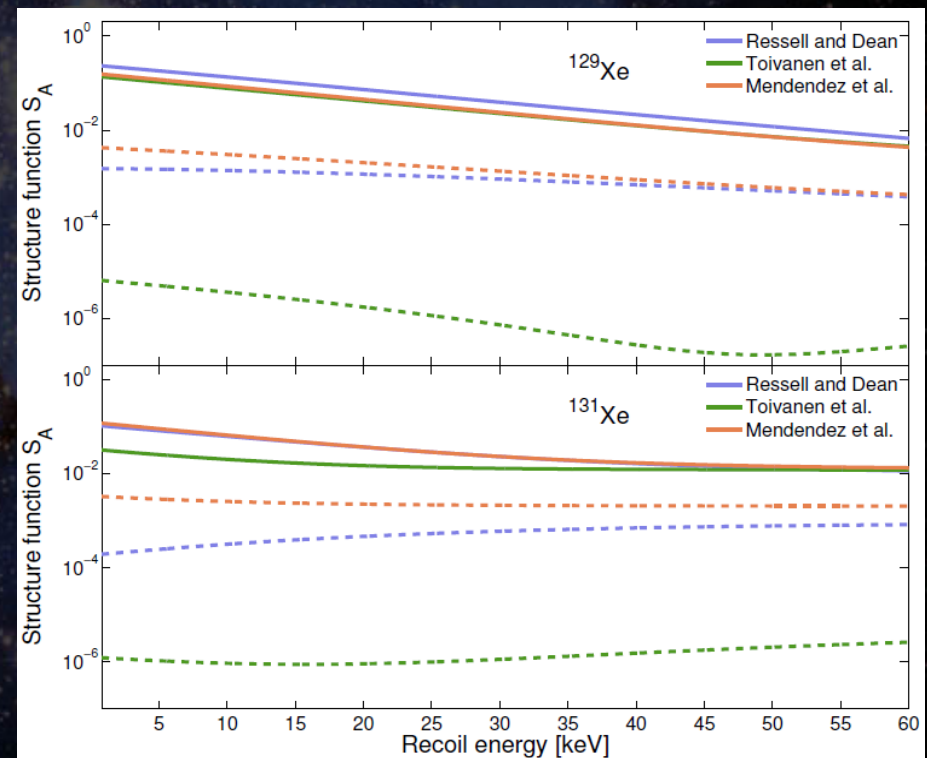
$$\frac{d\sigma_{SD}}{dq^2} = \frac{8G_F^2}{(2J+1)v^2} S_A(q)$$

Odd xenon isotopes, unpaired neutron

Different theoretical nuclear models:

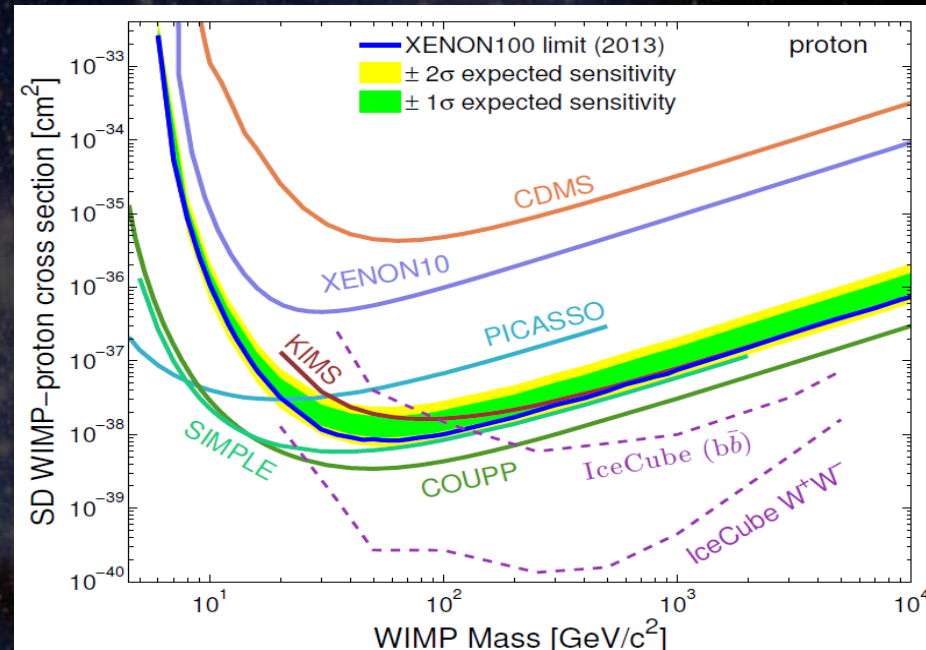
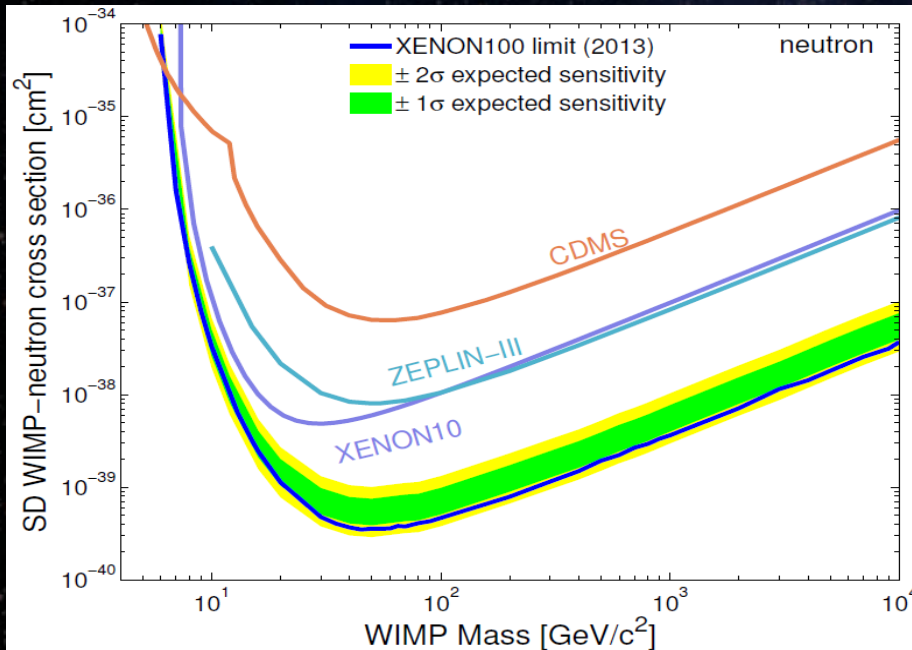
- Good agreement for pure neutron
- Large discrepancy for pure proton

Solid: pure neutron coupling  
Dashed: pure proton coupling



E. Aprile et al. (XENON100), Phys. Rev. Lett. 111 (2013)

# Spin Dependent Results



- Same data and event selection as SI search
- Set limit on pure neutron and pure proton coupling
- Most sensitive limit on pure neutron coupling above  $6 \text{ GeV}/c^2$
- $\sigma_n < 3.5 \times 10^{-40} \text{ cm}^2$  for  $45 \text{ GeV}/c^2$  WIMP

E. Aprile et al. (XENON100), Phys. Rev. Lett. 111 (2013)

# What's next for XENON100?

## New physics analyses

- Search for annual modulation
- Search for solar and galactic axions
- Light dark matter (S2-only analysis)

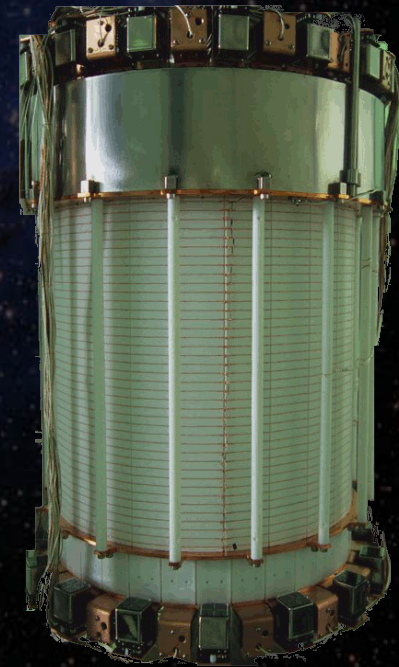
## Further detector characterization

- Response to single electrons
- Combined S1 and S2 NR energy

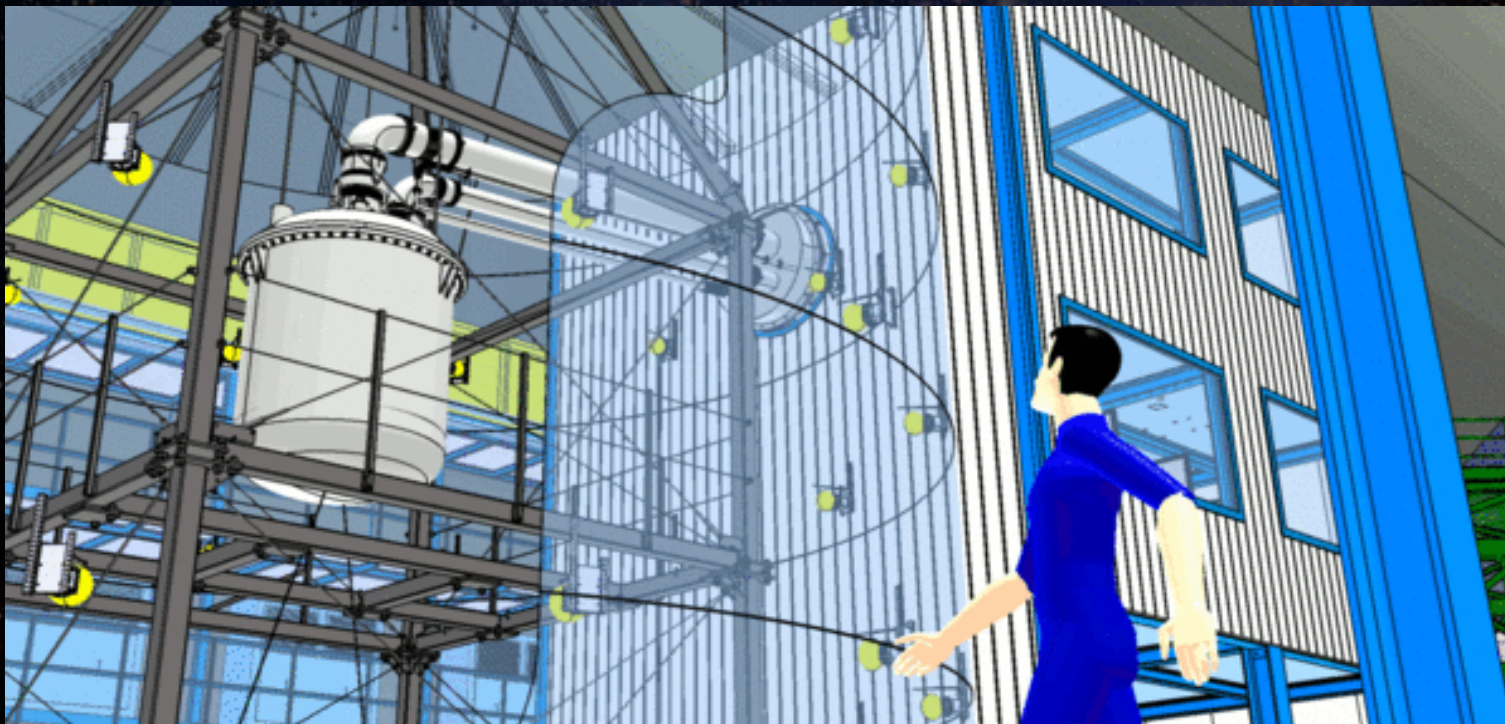
## Continued data acquisition

- New  $^{241}\text{AmBe}$  NR calibration
- Increased stats for ER calibration
- Further reduced Kr ( $1.8 \pm 3$  ppt)
- Investigate Rn reduction
- New calibration techniques for XENON1T

*Still Running!!!*



# XENON1T



- 2.2 ton target ( $\sim 1T$  fiducial)
- $\sim 1m$  height X  $\sim 1m$  diameter
- 9.8m water shield
- Reduce background 100X from XENON100
- Goal:  $< 1$  background in 2 years
- Increase sensitivity by factor 100

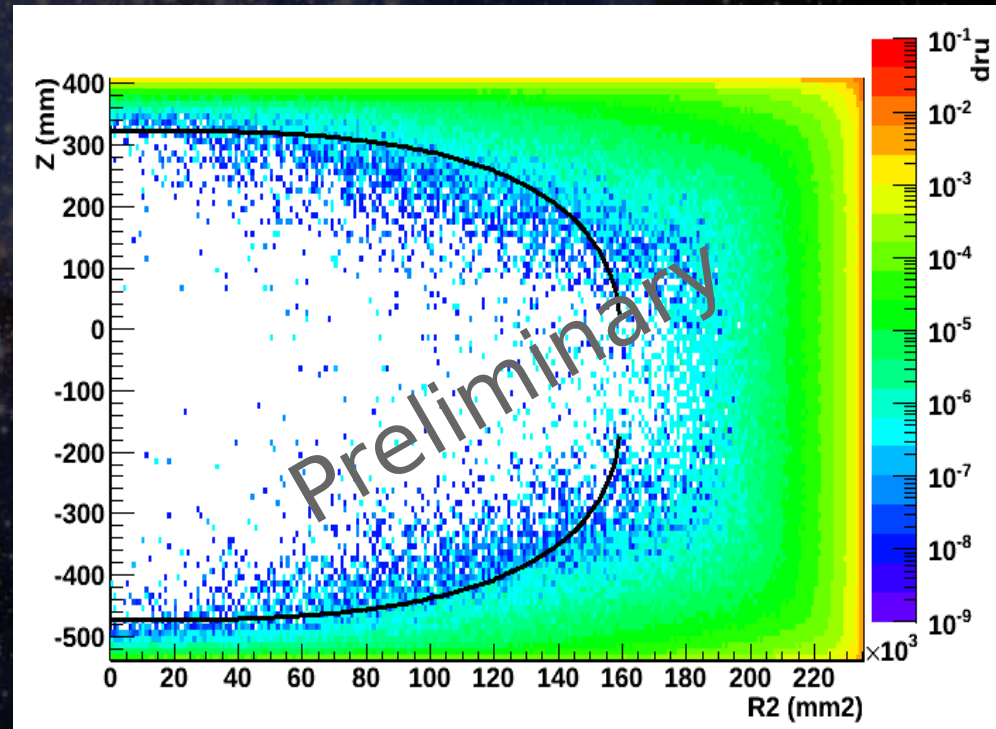
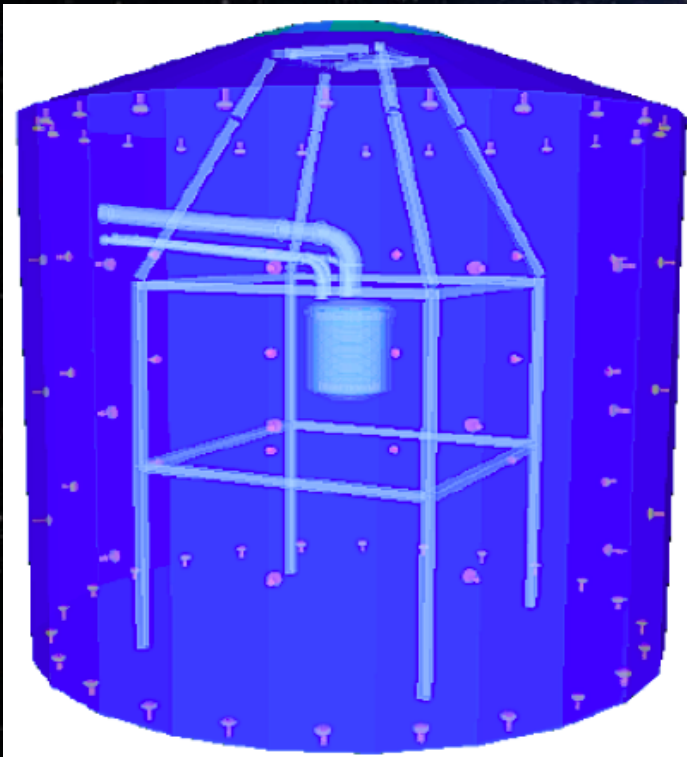
# Backgrounds for XENON1T

## Nuclear Recoils:

Tag muons in 10m water tank  
Materials with low activity in U/Th ( $\alpha, n$ )  
Reject multiple neutron scatters

## Electron Recoils:

External gammas stopped at edges  
Betas from internal impurities dominate  
 $^{85}\text{Kr}$ ,  $^{222}\text{Rn}$



# Reducing Intrinsic Backgrounds



Building cryogenic distillation column for Kr removal  
Aim: Kr/Xe < 0.1 ppt  
High throughput: 3 kg/h (3.5 tons in ~1.8 month)  
Custom gas purity diagnostics (online and offline)  
( $^{83\text{m}}\text{Kr}$  tracer, ATTA, RGMS, RGA + cold trap)



Reduce Rn emanation inside cryostat  
Aim:  $^{222}\text{Rn}$  < 1  $\mu\text{Bq}$   
Extensive emanation screening  
Attenuate Rn by passing xenon through charcoal filter

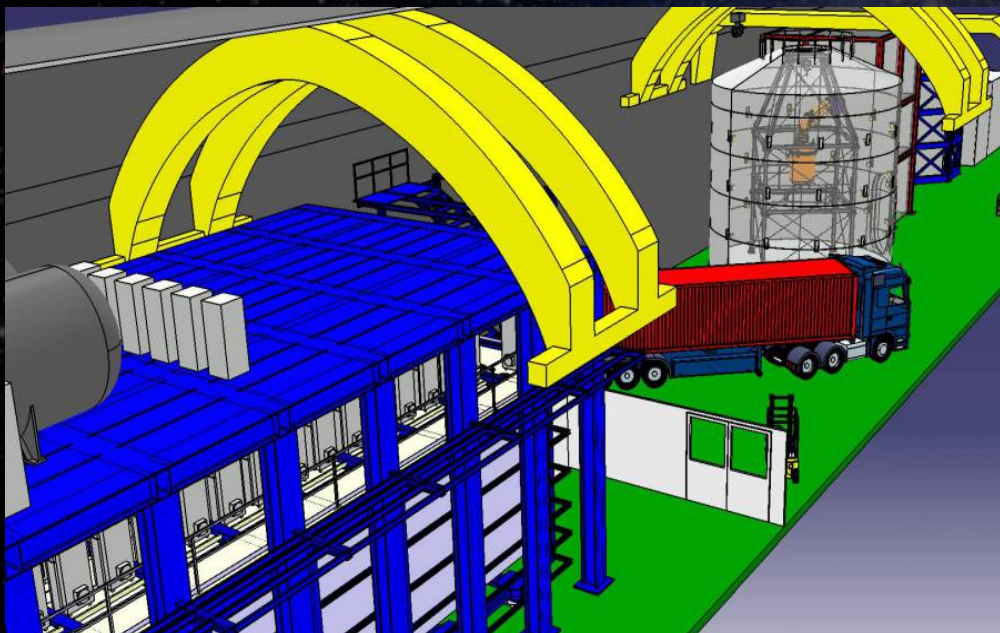
# Construction Started!

Water tank and building to be installed this year

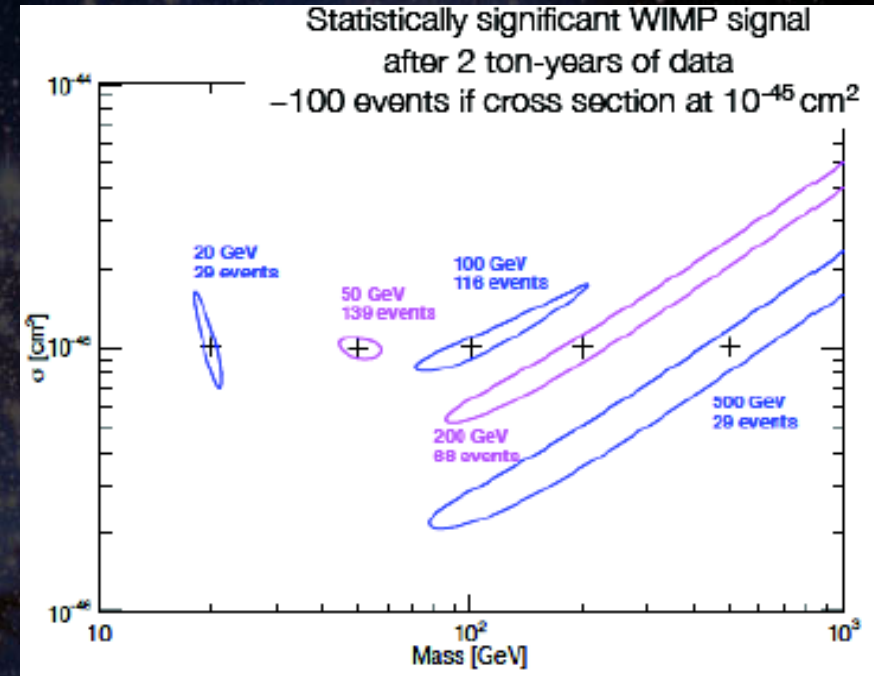
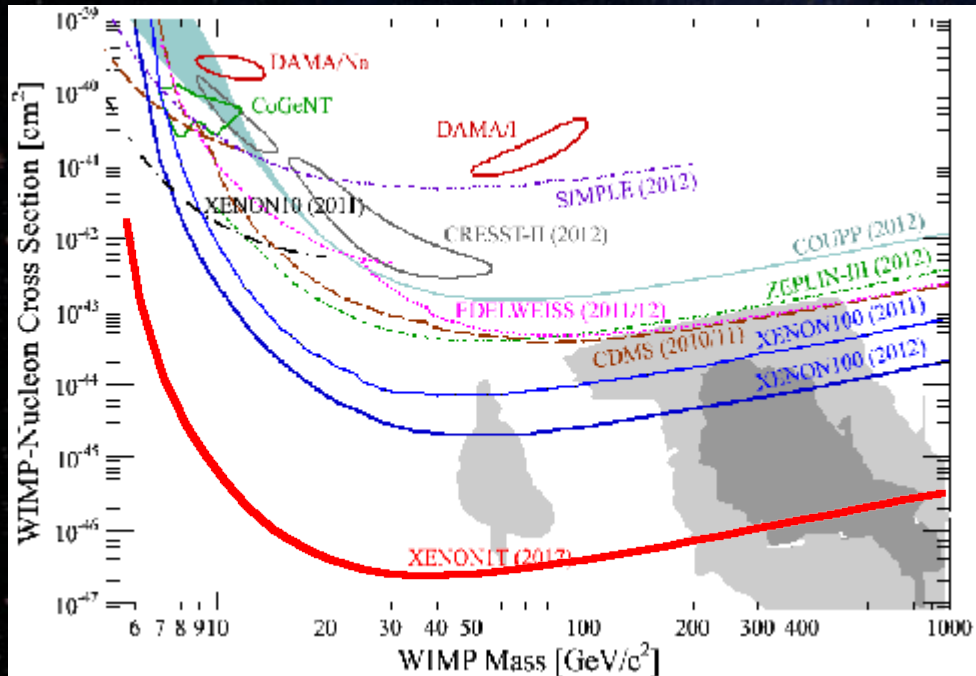
Other major systems installed starting January 2014

Commissioning in 2014

Science run to begin 2015



# Sensitivity of XENON1T



Example of discovery

$$\sigma_{\text{SI}} \sim 2 \times 10^{-47} \text{ cm}^2 \text{ for } 50 \text{ GeV}/c^2 \text{ WIMP}$$

Probe majority of SUSY-favored phase space

→ Strong discovery potential

Buchmueller et. al, arXiv:1112.3564 (2011)  
A Fowli et. al, arXiv:1112.3564 (2012)

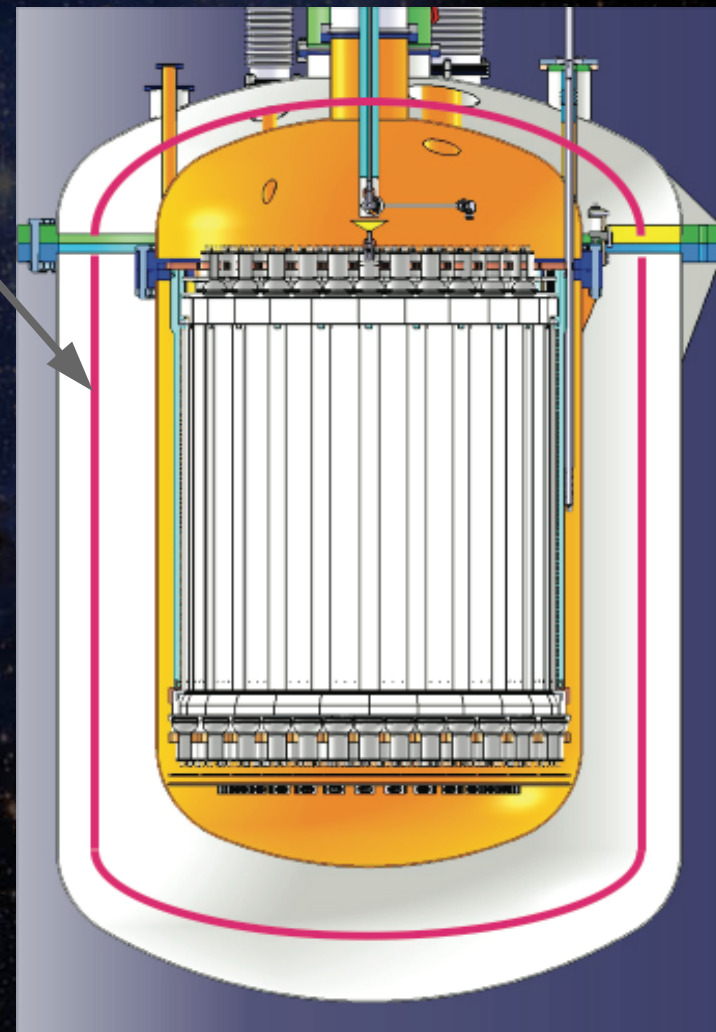
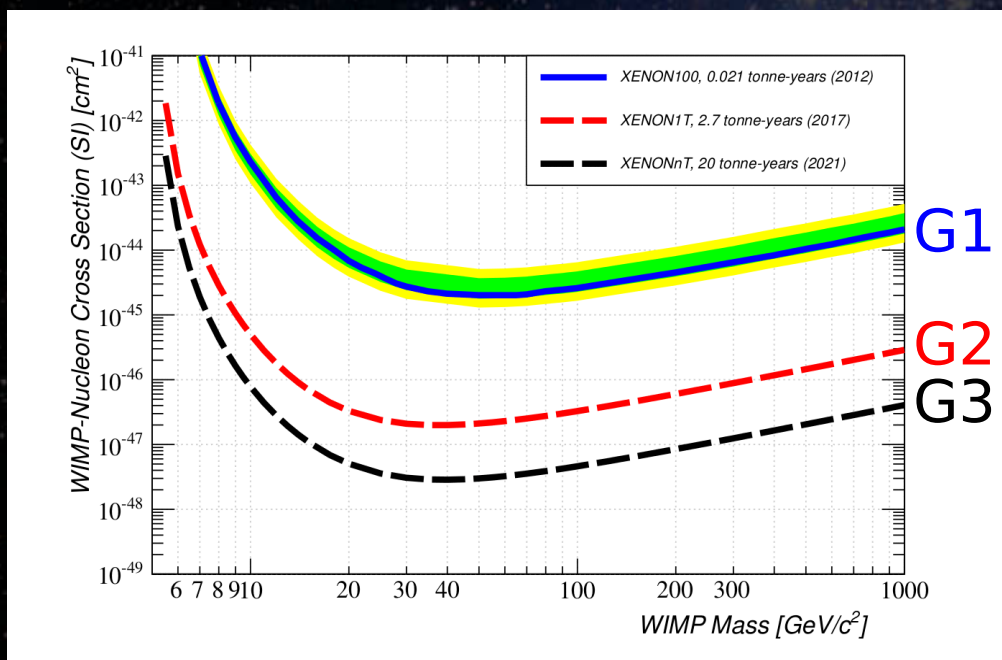
# Scaling it up again... XENONnT

XENON1T plus a larger TPC and inner cryostat

Everything from the outer cryostat out remains the same

Aim: 20 tonne-years exposure

Start date: 2018



# Summary

## XENON100:

- World leading limit on SI and SD WIMP-nucleon cross section
- Still running, new science and detector properties

## XENON1T:

- Now under construction at LNGS
- Commissioning 2014
- Science run 2015
- 2 ton-year by 2017

## XENONnT:

- Quick upgrade after XENON1T
- 20 ton-year by 2021



*We're all crazy  
about dark matter*